# Crack Tip Fields and Mechanisms of Fracture in Ductile FCC Single Crystals

Name of the student: Pinaki Biswas

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## Abstract

An understanding of crack tip fields and fracture mechanisms in single crystals can help in developing better polycrystalline alloys and manufacturing processes. To this end, the effects of loading rate, material inertia and strain rate sensitivity on crack tip fields and their influence on fracture mechanisms in FCC single crystals are examined in this work by performing finite element analysis. It is shown that, in the absence of inertial effects, high loading rates elevate the stresses ahead of a crack tip and decrease the plastic strains in rate dependent single crystals. Also, it is found that the quasi-static near-tip stress field can be adequately characterized by the energy release rate $J$ and a constraint parameter $Q$. Similar two-parameter characterization is possible even under dynamic loading. It is observed that if a suitable reference solution is used, the role of inertia manifests as a loss of constraint with increasing loading rate irrespective of strain rate sensitivity and lattice orientation. Thus, at very high loading rates, inertial effects oppose the role of rate sensitivity and cause a decrease in stresses near the tip. The relative influence of these two factors depends on rate sensitivity index. For a mildly rate dependent single crystal, the predicted cleavage fracture toughness remains constant up to a certain loading rate and thereafter increases sharply. On the other hand, for a strongly rate dependent single crystal, fracture toughness drops initially up to a certain loading rate beyond which it increases marginally. The loss of crack tip constraint is found to retard the ductile fracture mechanisms of void growth and coalescence. However, this is dependent on lattice orientation. In-situ experimental observation of void growth near a notch tip also shows strong orientation dependence. In addition, 3D finite element results indicate though-thickness dependence of equivalent plastic slip and hydrostatic stress leading to variations in void growth along the thickness direction of the specimens. The predicted load-displacement curves, lattice rotation, slip traces and void growth using finite element analysis are found to be in good agreement with the experimental observations. Thus, the present study has provided an understanding of the role of several factors such as constraint level, rate sensitivity, material inertia, lattice orientation and 3D effects on the mechanics of fracture of ductile single crystals.